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**Results for cod from the sentinel longline program
in the southern Gulf of St. Lawrence**

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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TABLE OF CONTENTS

Abstract.....	iv
Résumé	v
Introduction.....	1
Methods.....	1
Analysis	1
Results and discussion	2
Acknowledgements.....	2
references.....	2
Tables.....	3
Figures.....	4

ABSTRACT

Abundance indices for Atlantic cod, *Gadus morhua*, are derived from a sentinel longline program conducted in the southern Gulf of St. Lawrence from 1995 to the present. Based on information provided by fishers, fishing sites were established along the coast in traditional fishing areas. These sites were fished every year several times between July and October using standardized protocols. An annual biomass index for cod was derived based on catch rates which were standardized using a multiplicative model with factors for year, month, and site. The abundance index declined each year from 2005 to 2011, setting a new record low each year. No further declines in the index occurred in 2012 and 2013, though the values in these years remained near the record-low value of 2011.

RÉSUMÉ

Un indice annuel d'abondance pour la morue de l'Atlantique, *Gadus morhua*, est élaboré en utilisant des données de captures et d'efforts provenant d'un programme sentinelle à la palangre dans le sud du golfe du Saint-Laurent pour les années 1995 à 2013. Selon l'information fournie par les pêcheurs, les sites de pêche ont été établis le long de la côte dans les zones de pêche traditionnelles. À chaque année, ces sites ont été pêchés en utilisant des protocoles normalisés à plusieurs reprises de juillet à octobre. Un indice annuel de biomasse pour la morue est élaboré en utilisant les taux de capture normalisés avec un modèle multiplicatif qui comprend les facteurs année, mois, et site de pêche. Le niveau de l'indices annuel a diminué chaque année de 2005 à 2011, et à chaque année, le niveau était le plus bas jamais enregistré. La diminution du niveau de l'indice s'est arrêtée en 2012 et 2013 bien que les valeurs de ces années soient restées près de la valeur la plus basse jamais enregistrée de 2011.

INTRODUCTION

Sentinel surveys consist of limited removals from a fish stock following a scientific protocol established in consultation with the industry. The objective of these surveys is to provide abundance and biomass indices, additional to research vessel survey indices, for stocks where the fisheries are limited or under moratorium such as for the southern Gulf of St. Lawrence cod and white hake stocks (in NAFO division 4T). The sentinel longline program in the southern Gulf of St. Lawrence began in 1995. On each fishing trip, at-sea observers collect detailed information on the fishing activity, catch composition, and length frequency, as well as material for age determination. Since its inception, this program has been conducted using commercial fishing vessels fishing on historically important fishing grounds. A detailed description of the protocols and the results of the program from 1994 to 1998 is given in Chouinard et al. (1999). This report provides a summary of results for Atlantic cod (*Gadus morhua*) for the years 1995 to 2013.

METHODS

Five major regions in the southern Gulf of St. Lawrence (NAFO division 4T) are covered by the sentinel longline program: the southern Gaspé Coast, Gulf New Brunswick, Gulf Nova Scotia, Prince Edward Island, and the Magdalen Islands (Fig. 1).

The fishing locations (sites) are distributed along the coastline (Fig. 1). The gear for each vessel was deployed at two traditional fishing sites identified by the sentinel fishers (or their professional association). Once sites were established in an area, they remained fixed over the fishing season and all years. Each participant fishes two sites 2.5 miles in radius and at least 5 nautical miles apart. Typically, the gear for each vessel is fished between 8 to 15 times each year with a maximum frequency of twice per week over the period of the fishing season.

The longlines can be bottom longlines or "floated" longlines (1-3 feet off bottom). The soak time is set at a minimum of 4 hours and a maximum of 24 hours. In case of adverse weather, the gear must be retrieved as soon as possible after the storm has subsided. A minimum of 1,250 and a maximum of 2,500 hooks (size 12 circle – 1 fathom apart) are used per fishing trip, divided equally between the two sites.

Data were collected by a fishery observer on board each vessel. For each site and each time the gear was fished, information on the set location and a complete catch record was recorded. Details on the catch were also recorded. All fish and invertebrate species were sorted, weighed and counted. The length of up to 250 specimens was measured for each of cod and white hake. Otoliths were collected from among the measured cod (one per centimeter) and white hake (one per centimeter per sex).

ANALYSIS

Catch rates in the sentinel longline program were analyzed using a multiplicative model (Robson 1966; Gavaris 1980) with the SAS GLM procedure (SAS institute Inc. 1989) to obtain a standardized index of catch rates for this gear. The approach was similar to the one used in previous assessments of cod (Swain and al. 2009).

Observations of catch and effort for each individual site were aggregated on a monthly basis to partly remove the variability associated with individual fishing days, yet allowing for seasonal trends in catch per unit of effort (CPUE). Data cells (i.e. monthly aggregates) where catch was 0 or effort was less than 1,250 hooks were eliminated from the analysis. The data sets were then

examined for the number of missing cells and categories with many missing cells were removed from the analysis. Sites that have been fished in at least four years were included in the analysis. The sentinel longline index includes 44 sites from various areas in the southern Gulf.

Models that included interaction terms (year*site, year*month, month*site) were examined. Interactions were statistically significant but effects were small relative to the main effects of year, month, and site. Thus no interactions were included in the final model. The final model was as follows:

$$\ln A_{ijk} = \beta_0 + \beta_1 I + \beta_2 J + \beta_3 K + \varepsilon$$

where A_{ijk} is the catch rate for year i month j and site k ; I is a matrix of 0 and 1 indicating year; J is a matrix of 0 and 1 indicating month; K is a matrix of 0 and 1 indicating site. The model explained 63% of the variability in the data (Table 1).

RESULTS AND DISCUSSION

Since the last cod assessment in 2009 (Swain and al. 2009), a total of 17 vessels participated in the sentinel longline program in each year. Between thirty-eight and thirty-six sites were fished off the coast of the Gaspé Peninsula, New Brunswick, Prince Edward Island, Cape Breton and the Magdalen Islands. Fishing began as early as mid-July and was completed by the end of October or mid-November (depending on region).

Non-standardized catch rates by month and province are presented in Figure 2. The highest catch rates were made off northern New Brunswick (Miscou Bank, July to September), the northern coast of Prince Edward Island (August to September) and western Cape Breton (August to October) (Fig. 3a to 3e).

The standardized catch rate index declined each year from 2005 to 2011, setting a new record each year for the lowest value (Fig. 4). No further declines in the index occurred in 2012 and 2013, though the values in these years remained near the record-low 2011 value.

ACKNOWLEDGEMENTS

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TABLES

Table 1. General linear model statistics for the standardization of longline sentinel catch rates of cod from 1995 to 2013.

Factor	Levels	Values
year	14	1995 to 2013
month	4	7 to 10
site	44	17, 19, 22, 23, 24, 25, 28, 29, 30, 31, 34, 35, 40, 45, 50, 51, 52, 53, 60, 61, 65, 68, 71, 72, 75, 76, 85, 89, 97, 98, 103, 104, 109, 110, 113, 114, 115, 116, 121, 122, 123, 124, 125, 126

Number of Observations: 1,635

Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	64	3636.398524	56.818727	41.44	< 0.0001
Error	1,551	2126.638391	1.371140		
Corrected total	1,615	5763.036915			

R-square	Coeff. Var.	Root MSE	Catch rate mean
0.630987	29.55675	1.170957	3.961725

Source	DF	Type I SS	Mean square	F-value	Pr > F
year	18	221.812910	12.322939	8.99	< 0.0001
month	3	302.420317	100.806772	73.52	< 0.0001
site	43	3112.165297	72.375937	52.79	< 0.0001

Source	DF	Type III SS	Mean square	F-value	Pr > F
year	18	609.437659	33.857648	24.69	< 0.0001
month	3	51.153375	17.051125	12.44	< 0.0001
site	43	3112.165297	72.375937	52.79	< 0.0001

Year	LSMEAN Natural log of predicted catch rate (kg per 1000 hooks)
1995	3.764125
1996	4.130108
1997	4.560147
1998	3.803455
1999	3.912848
2000	4.261511
2001	3.852838
2002	3.779875
2003	3.753296
2004	3.985057
2005	3.525931
2006	3.25694
2007	3.02374
2008	2.855285
2009	2.562228
2010	2.372983
2011	2.341168
2012	2.641435
2013	2.673827

FIGURES

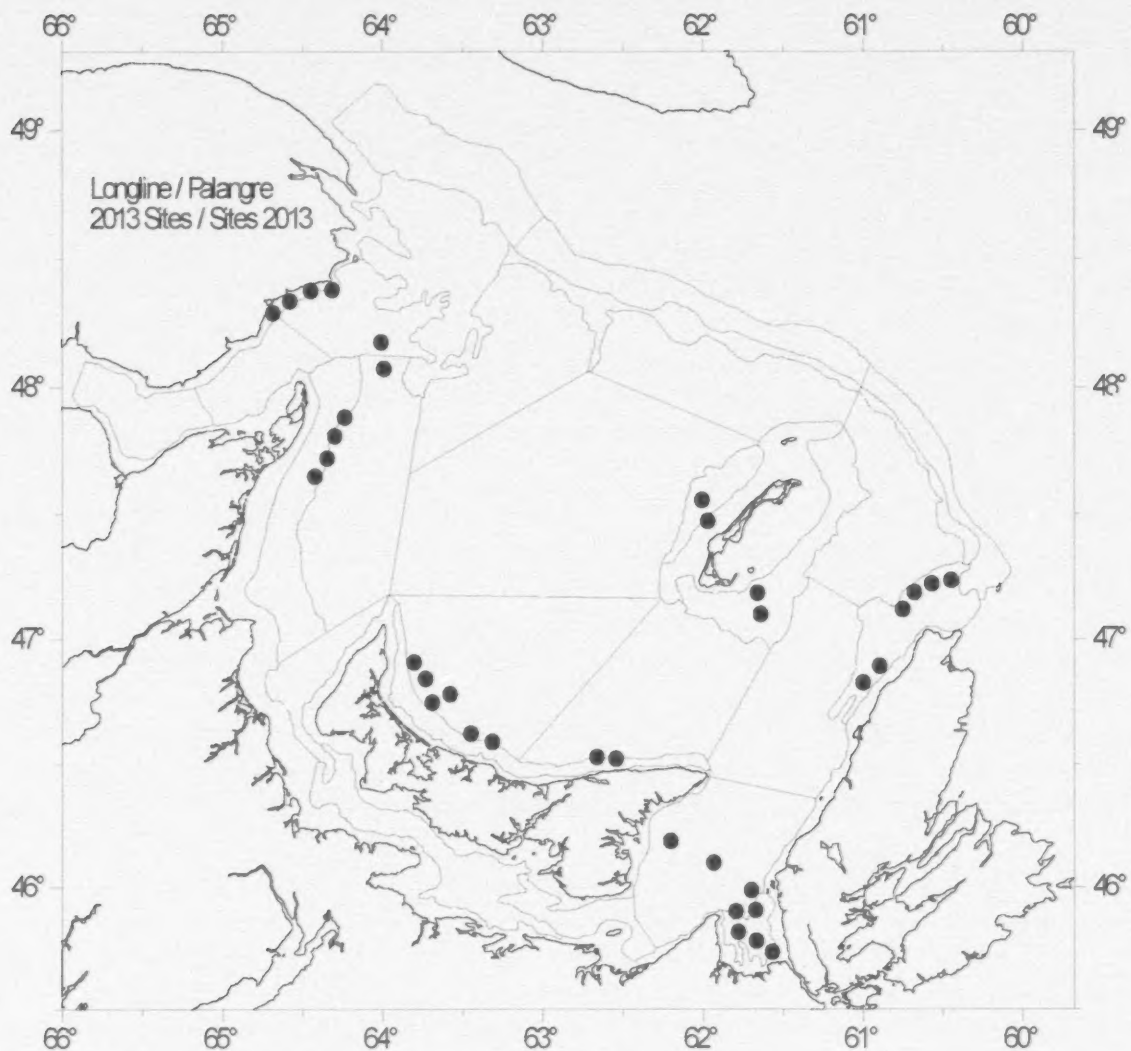


Figure 1. Positions of the sentinel longline sites for the 2013 survey.

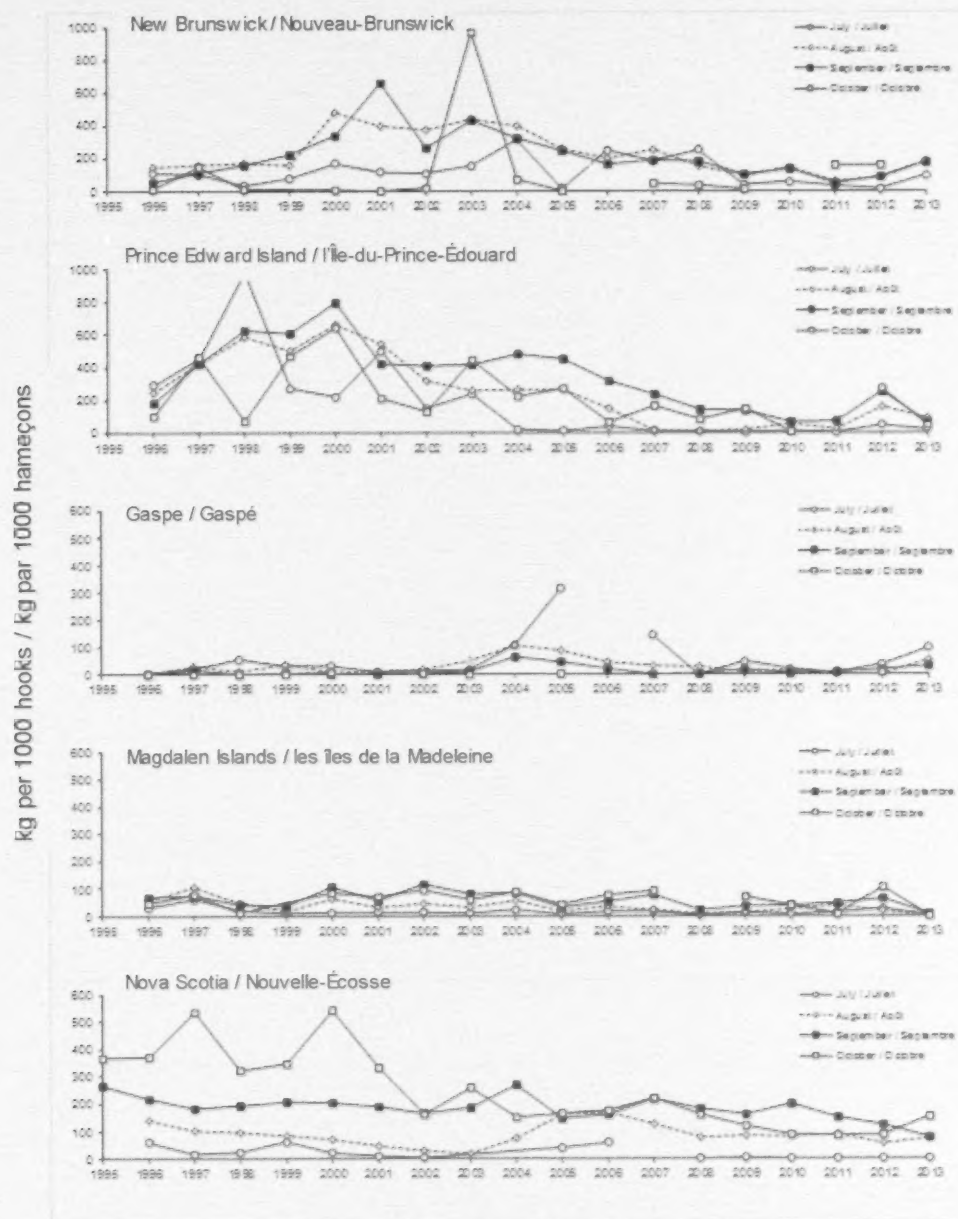


Figure 2. Annual non-standardized catch rates (kg per 1000 hooks) by month and province based on sites that have been consistently fished in the sentinel longline program, 1995 to 2013.

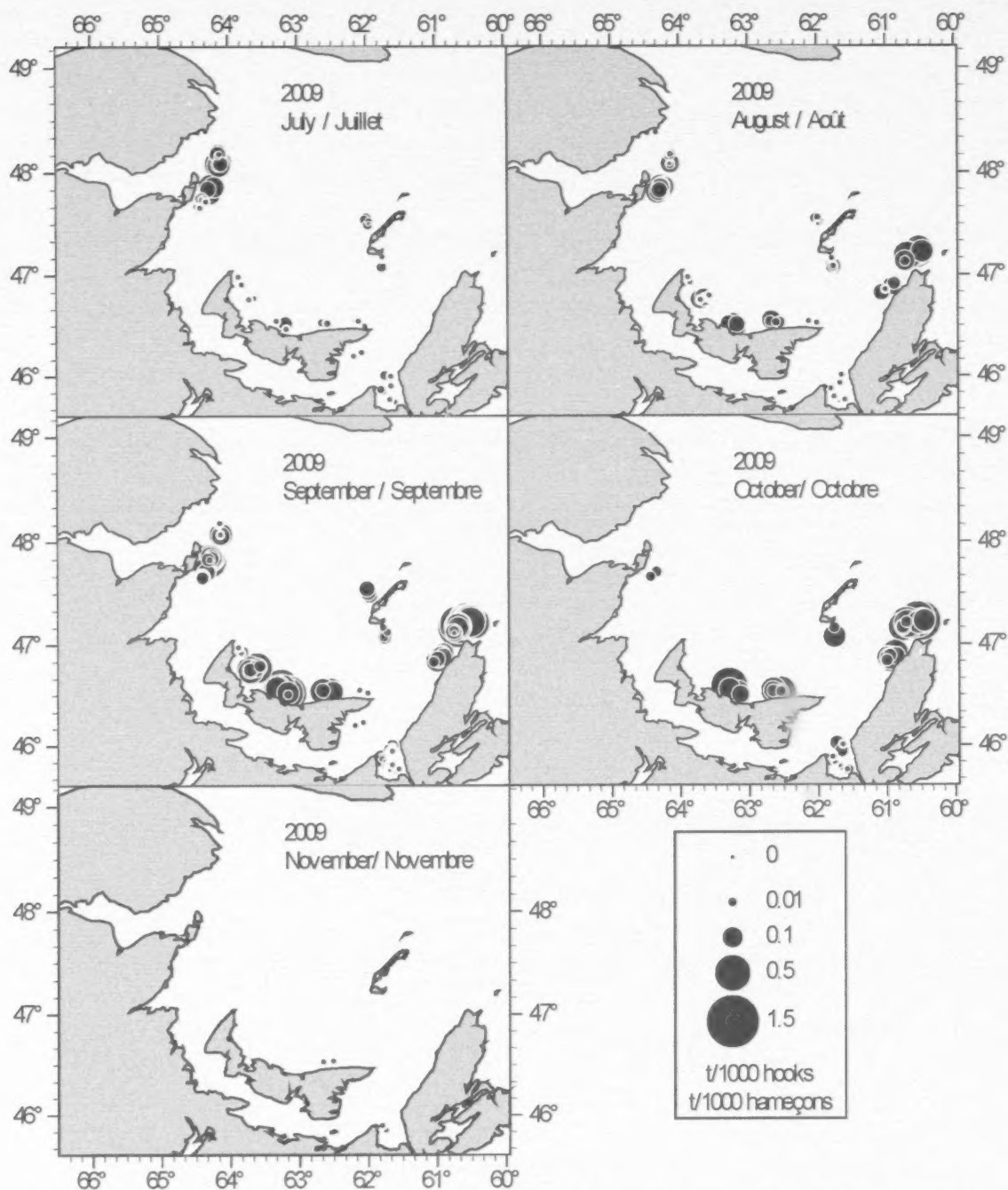


Figure 3a. Catch rates (t per 1000 hooks; circle area is proportional to catch rate) by fishing site during the sentinel longline program in 2009.

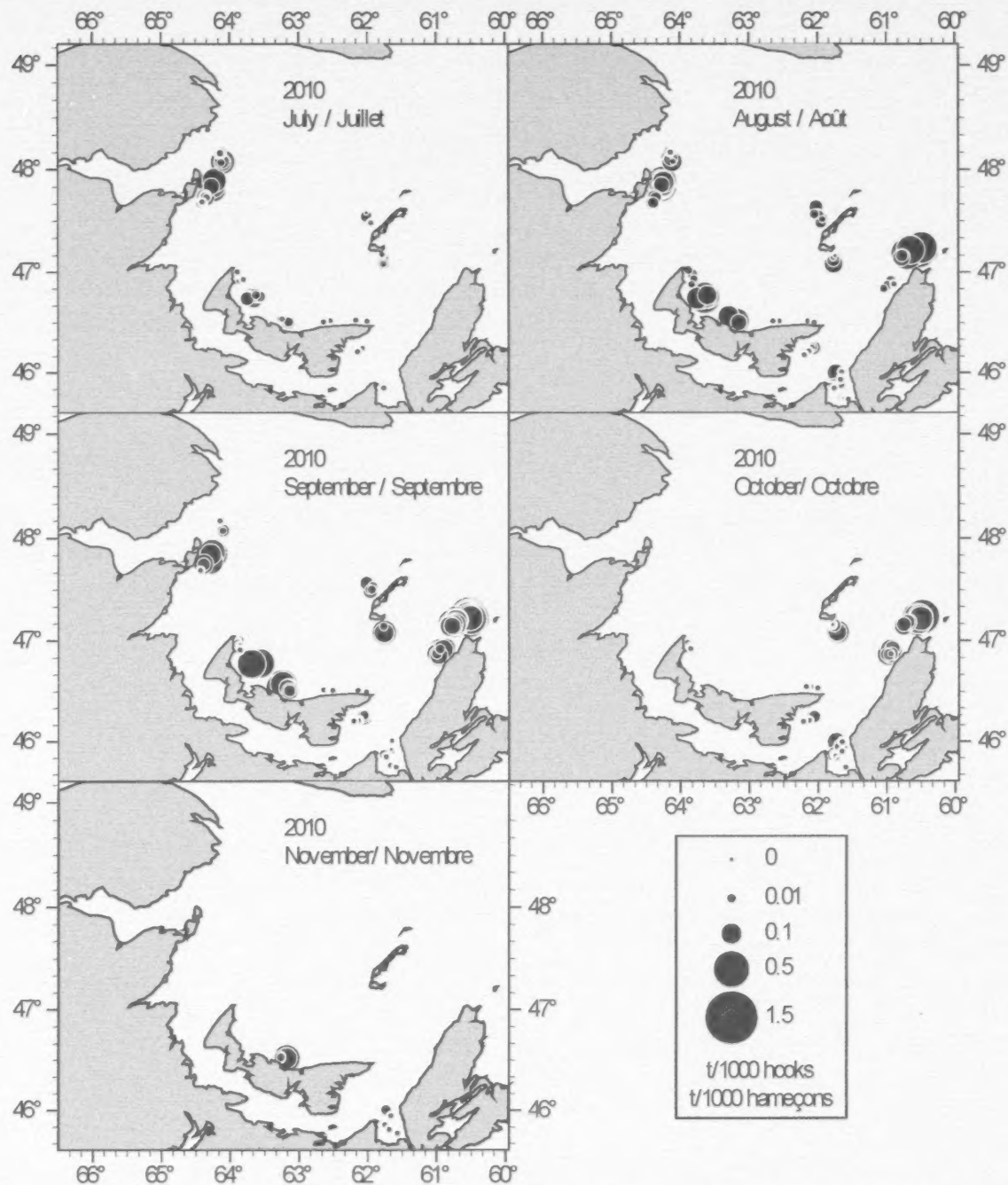


Figure 3b. Catch rates (t per 1000 hooks; circle area is proportional to catch rate) by fishing site during the sentinel longline program in 2010.

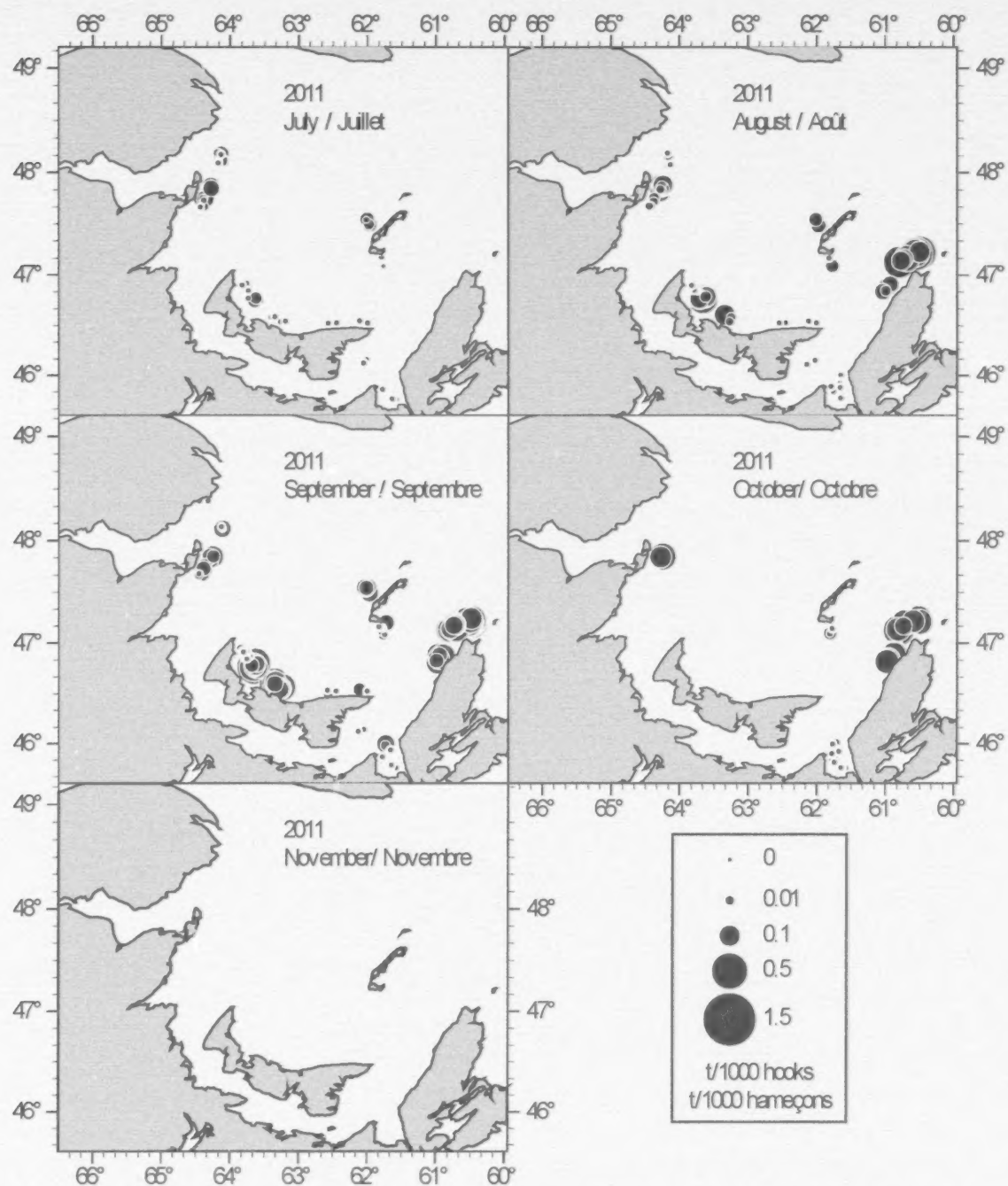


Figure 3c. Catch rates (t per 1000 hooks; circle area is proportional to catch rate) by fishing site during the sentinel longline program in 2011.

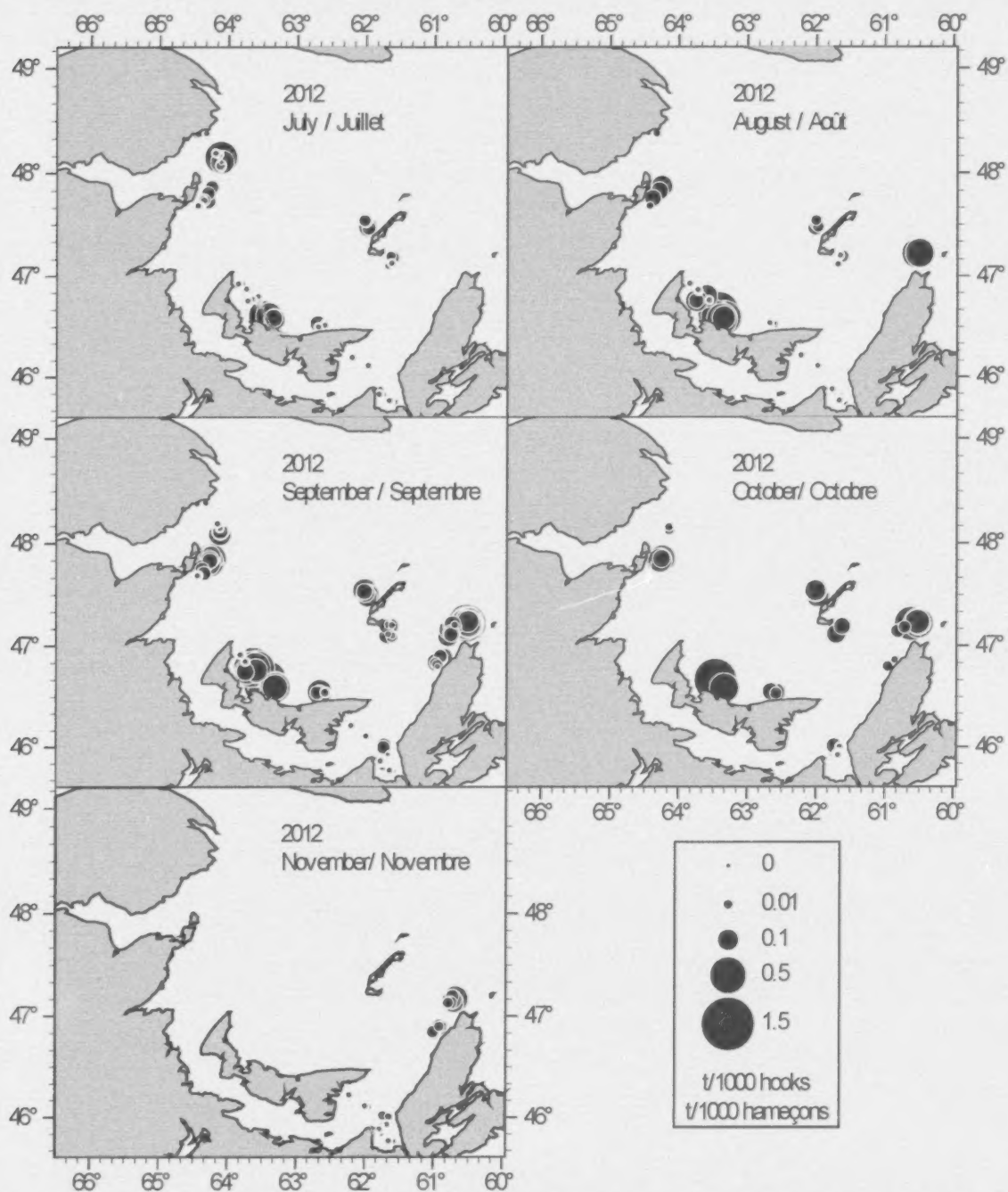


Figure 3d. Catch rates (t per 1000 hooks; circle area is proportional to catch rate) by fishing site during the sentinel longline program in 2012.

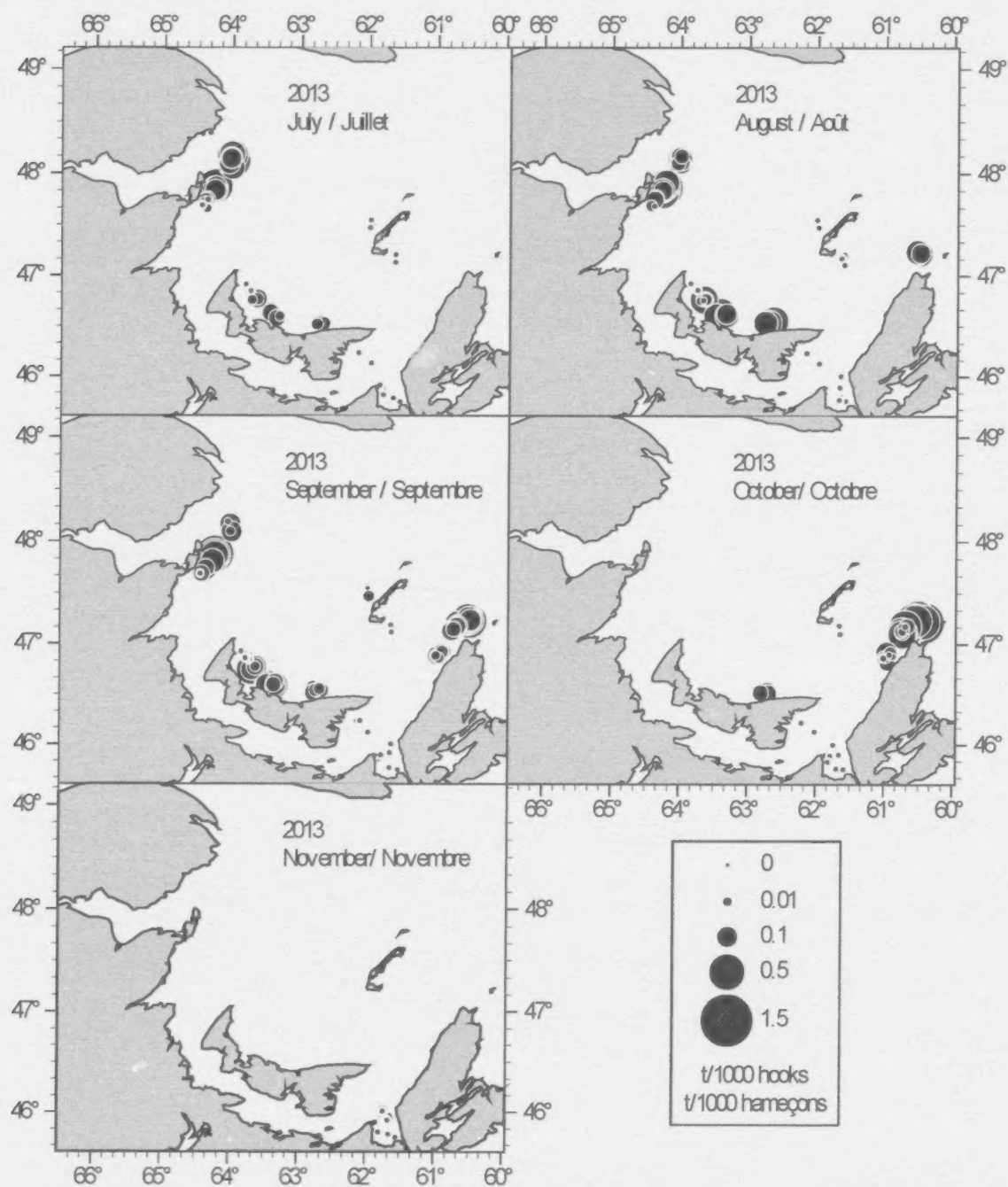


Figure 3e. Catch rates (t per 1000 hooks; circle area is proportional to catch rate) by fishing site during the sentinel longline program in 2013.

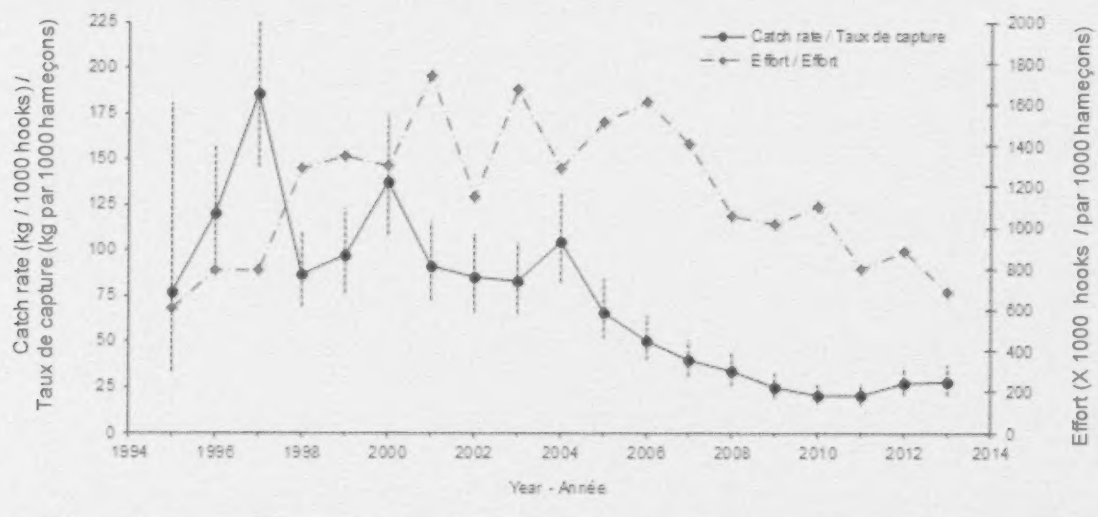


Figure 4. Annual standardized catch rates (kg per 1000 hooks; solid line, black circles are mean and vertical dashed bars are approximate 95% confidence intervals based on ± 2 standard errors) and effort (units of 1000 hooks; dashed line with annual diamond symbol) in the longline sentinel program in the southern Gulf of St. Lawrence, 1995 to 2013.